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The wildland-urban interface in Sweden

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Document coordinator	Frida Vermina Plathner
Contact	frida.vermina.plathner@ri.se
Authors	Frida Vermina Plathner (RISE), Johan Sjöström (RISE)
Reviewed by	Elsa Pastor (UPC)

Abstract	This study makes an attempt to describe the Wildland-Urban-Interface (WUI) of Sweden on 4 characteristic levels: The national level (describing the country as a whole), the regional level (in which the gradients within regions can be identifies), the community level (which identifies vulnerable areas and settlements) and the property level (in which the actions of homeowners are described). We use the WUI definitions developed for North America applied to a regular 1 km^2 grid. The Census blocks, onto which the American WUI is evaluated do not exist for many countries so a method of evaluating the WUI would be valuable for many regions and nations across the world. The results follow expected patterns across the nation, the WUI is scattered over Sweden, but the greatest extent is found outside Stockholm and Gothenburg and in Blekinge county, mostly in the form if intermix WUI in which buildings are scattered within the wildland. For the Community level, the chosen method is too coarse and an adaptation is applied and exemplified on a rural village in southern Sweden. The results, if possible to compare to Census based data, shows that Sweden has a relatively large portion of the area in the WUI but a smaller portion of the buildings within the WUI than both comparable states in the USA and the Spanish region of Catalonia. If these are results which holds in a grid size independent evaluation or on Census-like polygons are still unanswered questions. Some extent (4 %) of the Swedish building population is in vegetated areas that has too low population density to meet the selected WUI threshold of 6.17 units/km^2. However, these areas are also located where an elevated threat of a spreading wildfire exists. The dispatch distance for the rescue service is almost directly

	correlated to population density, therefore in practice tilting the responsibility of property protection to home owners in the WUI especially in mid and north Sweden. Also, although none of the last few decade's wildfires has directly threatened larger settlements the possibility of a fire spreading into more densely populated areas cannot be discarded. An inventory of the Swedish WUI at community level show that the defensible space around buildings with incombustible facades are similar to that for wooden ones. Decisions on fuel management is mostly done based on enabling sunlight (with a comparatively low angel) or moisture protection of buildings.

(1) Draft / Final
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1. Introduction

Many of the world's terrestrial ecosystems are historically shaped by wildfires which supports biodiversity and resilience. It is when wildfires occur in modern anthropogenic environments that large problems are faced. The wildland-urban interface (WUI) is the area where human-built structures or infrastructure mix with or meet wildland fuel (USDA & USDI, 2001). A coexistence of flammable fuel, structures and anthropogenic ignition sources in the WUI makes it a central concept for identifying developed areas that are at risk in the advent of a wildfire (Cohen, 2008). The WUI includes both (usually denser) settlements that adjoin a wildland area, designated as interface WUI, and sparser developments that are scattered within the wildland, designated as intermix WUI (USDA & USDI, 2001).

The past decades, WUI wildfires have caused increasing economic and social damage across the globe (Gill *et al.,* 2013). In Europe, this has been brought to attention by large events in the south such as the 2016 fires near Valencia where almost 2000 people were evacuated as two wildfires threatened residential and touristic developments. The year after, Portugal suffered WUI fires with consequences unprecedented in Portuguese history in which over 100 people were killed. Thousands of structures were affected, amongst them industrial amenities (Ribeiro *et al.,* 2017). During the 2018 European heat wave following year, a wildfire rapidly blazed over Attica, Greece, trapping families in their homes, resulting in over 100 fatalities (Molina-Terrén *et al.,* 2019).

Albeit more sparsely populated than southern Europe, the boreal part of the world, in which Sweden is located, has experienced a similar trend regarding WUI fires. In Canada, the 2016 Fort McMurray fire claimed over 2000 homes. Russian provinces of Irkutsk, Krasnoyarsk and Sakhalin, that together contain much of the country's boreal forests, have recent years experienced several large wildfires. One example is the 2014 fires in Irkutsk which resulted in 22 destroyed homes according to the Russian Emergency Ministry EMERCOM (Earth Observatory, 2020)[1]. In Scandinavia, 2014 saw several incidents with severe outcome such as winter event in Flatanger (Norway) with 60 buildings damaged (Log *et al.,* 2017) and Västmanland (Sweden) which resulted in one fatality and 71 structures lost. During 2018 the Ljusdal fires in Sweden claimed over 30 structures and hundreds of evacuated people. Although these events attract much attention, it should also be mentioned that many of the buildings ignited from vegetation fires concern small fires in the direct vicinity of dwellings increasing the importance of safety aspects on the property level rather than on regional or national level (Vermina Plathner *et al*, 2020).

Climate change implicates a prolonged fire season in parts of the boreal coniferous belt, including central Canada, Finland and southern Sweden (Flannigan *et al.,* 2009; Yang *et al.,* 2015). Consequently, the WUI in this region will also incur a higher risk of destruction from wildfire. Though, at presence, communities in Sweden are not adapted for dealing with large wildfires. There are no recommendations or requirements from either authorities or insurance companies to safeguard your home or garden from wildfires. Furthermore, little is known about the WUI in Sweden at national scale. For instance, no efforts have up to present date been conducted on identifying WUI areas with emerging fire threat to facilitate wildfire prevention plans.

[1] No official statistical report of wildfire-related property loss in Russia have been found for this study

The main purpose of this study is to identify the Swedish WUI and to characterize structures within the WUI. Since the concept of WUI was originally constructed in another context than the Swedish or Scandinavian we try to analyze how the concept applies in Sweden, what the Swedish WUI comprise of and give examples of characteristics which are possibly more common in Sweden compared to other regions.

We therefore try to describe and exemplify the Swedish WUI on four levels;

1. the **national level**, in which the national authorities such as the civil contingency agency or the forestry agency are responsible.
2. the **regional level**, where the regional administrations play an important role and which size is such that it spans over a few fire brigades or brigade associations.
3. the **community level**, in which municipalities, residential communities and local landowners can cooperate to increase resilience.
4. the **property level**, for which the individual homeowners are key for the level of safety.

The data produced in this work can, together with a wildfire risk assessment, be used at national scale to plan resource allocation or for local risk assessments by municipal fire rescue services, land or house owners.

2. Method

2.1. The Swedish wildfire regime

The Swedish Civil Contingency Agency has registered every fire leading to fire fighting dispatch since 1996. The data is assembled and corrected for faulty coordinates and areas as well as for duplicates by Sjöström and Granström (2020) to a data set of 86 585 incidents used in this study. Fire occurrence, i.e. frequency of wildfire per km^2 and year that has required a dispatch (Hardy, 2005), is calculated using the Kernel density Estimation (KDE) method in Quantum GIS (QGIS), with a radius of 5 642 m, uniform kernel shape and an output pixel size of 1 km^2. The removal of non-complete coordinate incidents lowers the calculated fire occurrence probability, but it is assumed that the spatial distribution remains intact.

Burn probabilities, i.e. the likelihood of a significantly spreading fire, is approximated by calculating the natural fire rotation (NFR) (Heinselman, 1973; Van Wagner, 1978).

$NFR = A_t/(A_f/N_y)$ (2)

where A_t is the total study area, A_f the total burned area from all fires in the considered period of time (N_y).

The NFR in Sweden was calculated by Drobyshev *et al.* in 2012, but since their study particularly dry summers in 2014 and 2018 have led to large fire episodes and the NFR is therefore re-calculated using the data set from Sjöström and Granström (2020). Burn probability is calculated as the reciprocal of the NFR ($pF_i = 1/NFR$). This data is interpolated over the land area using the Inverse Distance Weighted (IDW) method in QGIS. A distance coefficient of 2 and an output pixel size of 1 km^2 is used. Small fires are excluded (<1 ha) in the analysis, following the method by Finney (2005). The data with missing coordinates (see above) are almost exclusively smaller than this threshold, so the burn probability calculation is not significantly affected by the faulty data. These reported ignitions, with a final area over 1 ha, tallies to a total area of 4 254 ha.

2.2. Fire service density

The time to arrival for the fire service is one of the most important parameters that determine the total area burned in a wildfire (Sjöström & Granström, 2020). For instance, the initial dispatch team during the 2014 Västmanland fire received wrongful coordinates from the SOS operator and did not arrive at the scene until 1 hour later. At that time the wildfire had already grown out of their control.

Rural areas have a lower density of fire service and thus longer response times than urban areas. In addition, the closest fire station in rural areas is in general unmanned which implies a longer turnout time, Table 1. The conditions for obtaining help fast by the fire service is represented with GIS by measuring the distance the response team has to travel to structures.

Table 1. Types of fire stations in Sweden

Type of fire station	Definition	Expected turnout time (min)
Manned fire station	Is manned 24/7 with career fire fighters.	1.5
Unmanned fire station	Is not manned. Firefighting carried out by retained fire fighters that are obliged to respond on call.	5
Volunteer fire department	Volunteers may respond on call but are not obliged.	5

The closest distance from a fire station via the road network is calculated using the network analysis in GRASS GIS. Sampling is performed by random selection of 10 000 homes in each of the seven housing categories as defined by Table 2. An example from the analysis of high-density housing is seen in Figure 1.

Figure 1. Excerpt from the road network analysis. Black squares represent sample buildings from the high-density population and the red circles fire stations.

2.3. The extent of the wildland-urban interface at national and regional level

To outline the WUI with a geographic information system (GIS), an operational definition is needed. However, no regulatory definition exists due to the lack of Swedish recommendations or requirements regarding structure protection from wildfires in the WUI. Furthermore, a common definition neither exists in Europe (Modugno *et al.,* 2016). For the purpose of this study the U.S. Federal Register definition operationalized by Radeloff *et al.* (2005) is therefore used: The WUI has a minimum of 6.17 housing units per km^2 (≈one unit per 16 ha) and is divided into intermix and interface WUI. The intermix WUI is dominated by wildland (that is: > 50 % vegetated area). The interface WUI is not wildland dominated (< 50 % vegetated area) but is located less than 2.4 km from a > 5 km^2 wildland area with a vegetation density of at least 75 %.

Detailed data on housing density in Sweden is derived by counting residential building polygons in a 1 km^2 grid. Thus, the area in which the housing density is calculated is fixed to a 1 km^2 grid. The data is retrieved from the building map by the Swedish National Land Survey (2020) and contains all registered buildings in the country. All buildings which are not homes or summer houses are discarded to align with the US Census data used by Radeloff *et al.* (2005) and the remaining number of buildings is 4 141 597. Vegetation is described by a terrestrial raster map (grid cell size of 100 m^2) produced by the Swedish Environmental Protection Agency (2020) based on the CORINE land cover European classification system. In "wildland vegetation" we include all tree-covered land such as coniferous, mixed forest, and deciduous, but also clear-felled/transitional land, tree-covered mires and shrub. Non-wildland is open wetland, arable land, open land without vegetation and urban settlements. For each 1 km^2 grid cell the wildland percentage is calculated.

The national WUI map is produced with categories defined in Table 1.

Table 2. Categories used for the WUI map at national and landscape scale (1 km^2 grid)

Housing category	Housing density (units/km^2)	Vegetation density criterion
Vegetated, no housing	0	> 50 %
Vegetated, low-density housing	0 – 6.17	> 50 %
Non-vegetated, no or low-density housing	0 – 6.17	< 50 %
Intermix	6.17 – 49.42	> 50 %
Interface	6.17 – 49.42	< 50 %, but located less than 2.4 km from a > 5 km^2 wildland area with > 75 % vegetation density
Medium- to high-density housing	> 49.42	-

2.4. The WUI at community level

A common WUI definition, e.g. the one specified by USDA and USDI, allows for comparison of WUI areas between countries and may work at national level to define priority zones for the Swedish authorities. However, characteristics of the Swedish landscape and how they relate to the country's specific wildland-urban fire challenges are not considered in such analysis. The downscaling of a WUI map from regional to community level imposes problems given the grid size that evaluates wildland coverage and building density. Thus, keeping a 1 km^2 evaluation grid size at a community level will induce problems of coarseness that cannot describe the community aspect since it leaves out important features of the transition zones between urban and wildland cover. Therefore it looses the important aspect of the finer resolution to evaluate the densities of housing in smaller areas (100 000 m^2) and to represent these evaluations in even smaller areas (100 m^2). However, a too small grid size will result in too steep gradients of building density from +50 % to 0. Radeloff et al. (2005) used census blocks to obtain statistics, which are irregularly shaped areas bounded by roads, administrative boundaries, rivers etc. These type of mapping blocks makes the boundaries of evaluation areas more natural from a community perspective and will automatically shape towards the relevant size at the specific location. Such block are unfortunately not available for Sweden as of now and in absence of these, a country-specific definition of the WUI at the community level could be appropriate.

Another argument for defining a country-specific WUI is that the majority of large wildfires in Sweden burn with low intensity. Low-intensity fires produce fewer burning embers and the pathway to ignition of structures is therefore often by direct flame impingement (Vermina Plathner *et al*, 2020). The USDA definition of *Interface* relates to a criterion where burning embers constitute a severe and common threat. It is believed that the majority of structures in the US are ignited by embers (Gollner *et al.*, 2015). In Sweden, only a handful of all fires the past 20 years have been partially crowning fires. Although structure ignition by embers occasionally exist (and have the potential of being a major hazard in future incidents) the occurrence is too rare to support an *Interface* definition relating to ember ignition at up to 2.4 km distance (Granström, 2020). A more valid definition for Sweden would be to leave out the 2.4 km criterion and instead use "Medium- to high-density housing that abut wildland".

In order not to obtain several WUI areas within green patches in urban areas we include a population criterion for the WUI types of > 50 people in the community defined by data from Statistics Sweden (2020).

Based on the above arguments an operational definition for the Swedish WUI that can be used at community level is specified in Table 3.

Table 3. Criteria for a suggested Swedish-specific definition of the WUI at the community level

	Type	Housing criteria	Housing density criteria (units/km^2)	Wildland criteria	Buffer zone
Non-WUI	Vegetated, no housing	More than 56.42 m from construction (radius of a 0.01 km^2 large circle)	0	Wildland	-
	Vegetated, low-density housing	Within 56.42 m from construction	Housing density, evaluated in a 0.1 km^2 area (r=178.4 m): <6.17	Wildland	-
	Non-veget., no housing	More than 56 m from construction	0	Not wildland	-
	Non-veget., low-density housing	Within 56 m from construction	Housing density, evaluated in a 0.1 km^2 area (r=178.4 m): <6.17	Not wildland	-
	Medium/high density	Within 56 m from construction & population > 50 people	Housing density, evaluated in a 0.1 km^2 area (r=178.4 m): >6.17	More than 40 m from wildland	-
	Water	-	-	Water	-
WUI	Intermix	Within 56 m from construction & population < 50 people	Housing density, evaluated in a 0.1 km^2 area (r=178.4 m): 6.17-49.42	Within 40 m from wildland	Within
	Interface	Within 56 m from construction & population > 50 people	Housing density, evaluated in a 0.1 km^2 area (r=178.4 m): 6.17-49.42	Within 40 m from wildland	Outside

The population density of a rural settlement in south Sweden is shown in Figure 2. The evaluation areas for the densities are specified in Table 3 and each cell in the terrestrial map is evaluated (100 m^2, 10x10 m). Areas that could be categorized as WUI are the orange and red colored ones.

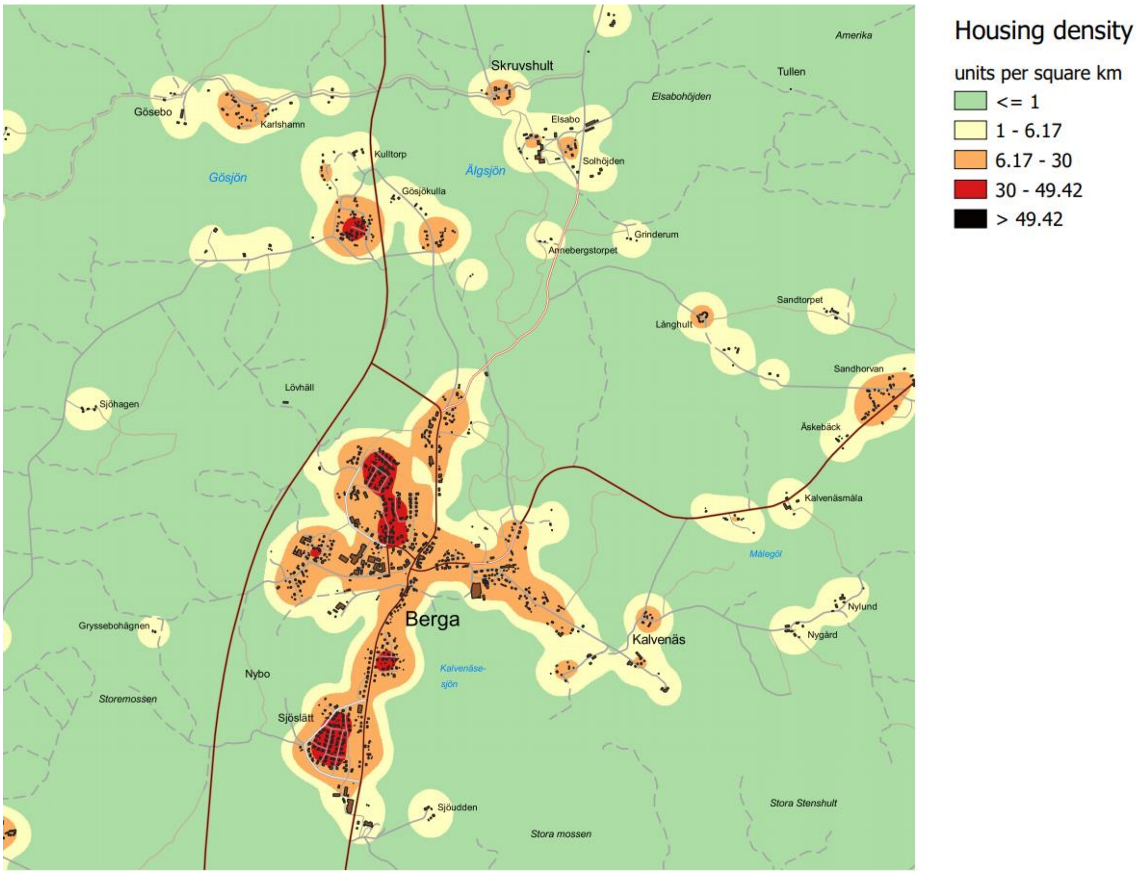

Figure 2. Housing density in Berga village, evaluated with KDE using a radius of 178.4 m. Intermix requires a housing density between 6.17 and 49.42 units/km².

Structure survival is primarily a function of the home ignition zone (HIZ), i.e. the structure itself and the natural and artificial fuels in a 30-50 m radius (Cohen, 2000). Guidelines and regulations for wildfire protection therefore often prescribe a minimum defensive space around the structure, in which the primary goal is to reduce or remove ignition sources and fuels. Spanish regulations specify a defensible space of 50 m (Ley de Montes 43/2003). Another safety distance mentioned in the literature is 10 m, which is an experimentally indicated minimum safety distance for wood panels to not be ignited by radiation from a crown fire (Stocks et al., 2004; Cohen, 2000).

Many houses, that typically represent the interface between wildland and settlements will be categorized as intermix since from the definitions above. Therefore, strictly for the *community scale*, the interface WUI also require inclusion in a *buffer zone*. This is constructed by buffering the wildland 40 m into the populated area. The populated area within the interface is similarly constructed by expanding the area 56.42 m into the wildland (corresponding to the radius of a 10 000 m^2 circle), Figure 3. The overlapping areas are considered interface at community level, given that the other requirements of Table 3 are fulfilled.

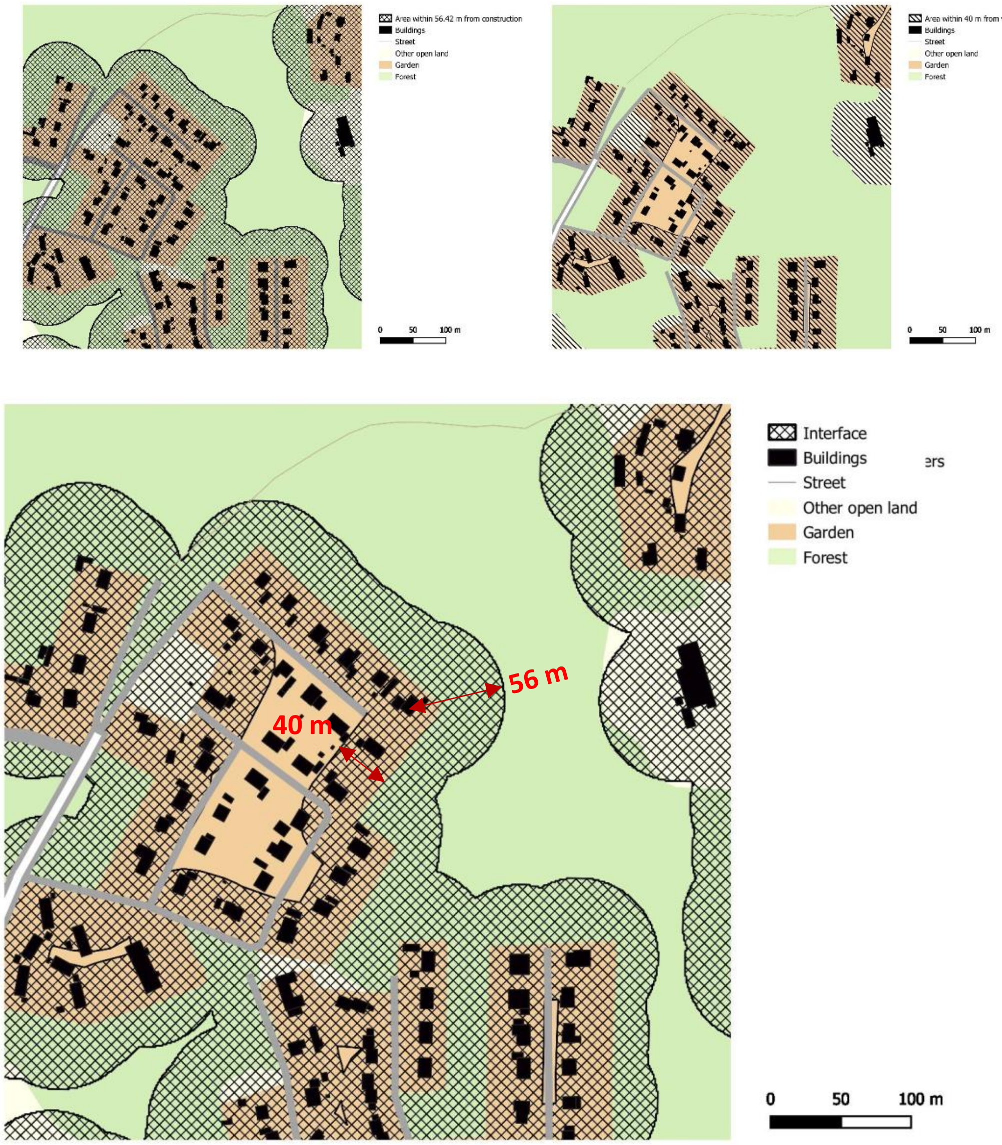

Figure 3. Construction of community scale interface. (Top left) Expansion of the populated area into the surrounding by 56 m. (Top right) Expansion of wildland into populated area by 40 m. (Lower) Combination of the expansions into an interface.

The community scale *Intermix* also requires a housing density of 6.17-49.42 units/km^2 to represent scattered settlements and housing within the wildland. The building density is evaluated with the KDE tool using a radius of 178.4 m, corresponding to an area of 0.1 km^2, Figure 2. An area is considered intermix if the settlement is inhabited by less than 50 people, located within a wildland area and not in a buffer zone.

2.5. The WUI at property level

WUI at property level is represented by the structures, the garden and any other features in the immediate surrounding (30-50 m radius) of the structure (Cohen, 2000). A GIS analysis is conducted to retrieve a general idea of what type of vegetation that surrounds constructions in Sweden. The results are retrieved with the Zonal Statistics tool in QGIS, where vegetation data is extracted in an extended perimeter (buffer) around each Swedish residential building, using offset distances of 10 and 50 m. The data is aggregated over all the buildings in each housing category.

Additionally, to obtain a more detailed study of what is included in the Swedish WUI, a field study is conducted in which we try to exemplify the characteristics of the WUI at the property level. We examine two typical WUI settlements in closer detail to represent typical home ignition zones (HIZ) in Sweden; (1) a rural village of single dwellings, and (2) a settlement of townhouses in a suburb to a larger city, their approximate locations are displayed in Figure 4. The study is not intended to be statistically representative of all Sweden's WUI but are used as two common examples of settlements where risk of structure damage from wildfires should be taken into account.

Figure 4. Case study locations

The study includes two different types of settlements.

Rural village

Berga is a rural village of single dwellings in south-east Sweden, in Högsby municipality. The village has a population of 784 (2019) and about 300 properties, Figure 5. Most properties have one residential building and one or more outbuildings. The village was constructed in three different decades with the oldest houses from 1940s-50s, followed by expansion during 1960s and 1980s. The buildings selected in the inventory (those with a direct boundary to wildland, excluding ones adjacent to wet mires or to strips of forests less than 100 m wide) sum up to 76 with 170 structures on them.

Berga lies on a higher plateau with lean soil, which its characteristic pine forests. The forest is mostly production forest with patches of arable in it. The region experiences, second of Stockholm county, the most high-fire danger days in the country and is notorious for high summer temperatures by Swedish standards.

Figure 5. Satellite image of the rural village of single dwellings for the inventory (Google maps)

Suburban townhouse settlement

30 km outside of Gothenburg (Sweden's 2nd largest city) lies Floda in which outskirts a townhouse settlement built in late 1980s and early 1990s is situated, Figure 6. It lies on a high hill with steep slopes to surrounding forest, mostly used for recreational purposes. Close by is a high voltage powerline.

All houses have wooden facades, consist of one or two stories and each building contains two attached properties. In total we add 66 properties to our inventory of which 5 are non-residential.

Figure 6. Satellite image of the suburban townhouse settlement for the inventory

Inventory

The inventory only addresses properties with a direct boundary towards the wildland. Thus, a property with neighboring properties on three sides and a road on the fourth side is not taken into account, even if wildland extends just on the other side of the road. Doing this enables us to focus on the high-risk properties.

The characteristics addressed in the inventory are shown in Table 4.

Table 4. Properties collected in the inventory

Characteristic	Variable	Comment
Function	Dwelling/outbuilding/commercial	
Façade material	Timber	
	Brick	See Figure 5
	Plaster (mortar)	
Roof material	Tiles	
	Metal	See Figure 5
	Bituminous waterproofing	
Vegetation fuels in garden	High	
	Medium	See Figure 6
	Low	
Other fuels in garden	High	
	Medium	See Figure 6
	Low	
Fuels against façade	High	
	Medium	See Figure 7
	Low	
Slope against garden from wildland	High >30°	
	Medium <30°	
	Low ~0°	
Existence of a wooden deck or balcony facing the wildland	Yes/no	
Distance from façade to the wildland	Meters	
Type of boundary to wildland	None/hedge/wooden fence/metal fence/overgrown fence …	

Figure 7. (1) Townhouse with timber façade and tile roof. (2) single dwelling with plaster (mortar) façade and tile roof. (3) Outbuilding with timber façade and metal roof.

The amount of fuel load in the gardens and against the facades are assessed on a three grade scale as what is considered low, medium and high risk regarding spread from a wildfire to the structure, see Figure 8-Figure 9.

Figure 8. Example of vegetation (upper panels) and other (lower panels) fuel load in gardens according to the three classes Low/Medium/High. Photos: Johan Sjöström.

Figure 9. Example of fuel load against the façade. Photos: Johan Sjöström

3. Results

3.1. The extent of the wildland-urban interface at national and regional level

Tallying all the 1 km^2 cells on a national level the WUI in Sweden covers 60 000 km^2, including 929 824 housing units, i.e. 14 % of the land area and 23 % of the number of houses. Although WUI areas exist across the entire country, the bulk extent is in the south, specifically outside the two largest cities Stockholm and Gothenburg, and in the south-east (e.g. Blekinge county with approximately 35 % WUI area), Figure 10. In general, the WUI (and settlements overall) is located along coastal and lake shorelines as well as watercourses. Intermix areas are more common than interface WUI due to the continuous vegetation cover that extends all the way up to (and into) the perimeters of cities. Only the most southern county (Skåne) and the area south of the largest lake (Vänern) have large percentages of agricultural land cover. Intermix WUI comprise 13 % of the land area and 20 % of the housing units whilst interface WUI covers 2 % of the total land area and holds 3 % of the building population, Table 5. The rest of the building population is dominated by high density housing (73 % of all residential buildings) despite covering only less than 4 % of the total area. Almost 7 % of the buildings are situated in low density (i.e. <6 buildings per km^2) areas, mainly in the forests.

Table 5. Fraction of houses (dwellings) and land area (total land area 410 000 km^2) in the different categories.

General	Category	Buildings	Area	Buildings	Area
WUI	Interface	3.1 %	1.9 %	23.1 %	14.5 %
	Intermix	20.0 %	12.6 %		
Non-WUI, vegetated	No housing	0 %	58.5 %	4.3 %	73.4 %
	Low density housing	4.3 %	14.9 %		
Non-WUI, not vegetated	No housing	0 %	5.6 %	72.7 %	12.1 %
	low density housing	2.3 %	2.7 %		
	High density housing	70.4	3.8 %		

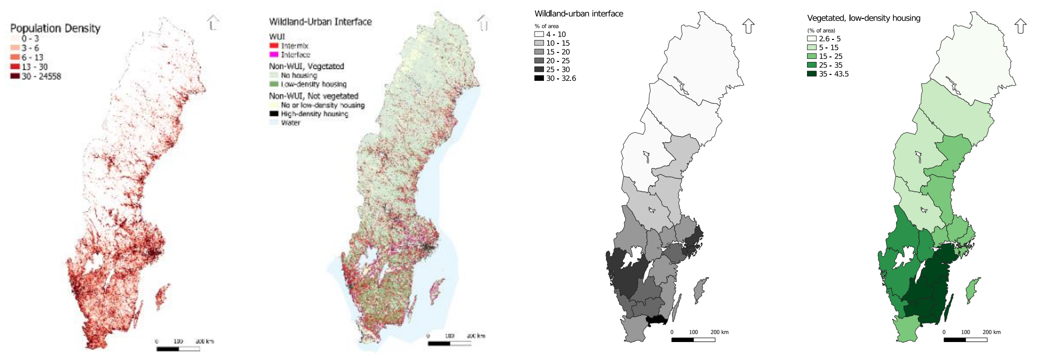

Figure 10. (a) Population density (Source: Swedish Statistics) (b) The wildland-urban interface according to the USDA definition, (c) County level scale: Percentage of area within the WUI, and (d) County level scale: Percentage of area that is vegetated with low housing density.

At landscape level (Figure 11-Figure 14) it is seen that the WUI appears in patches across the landscape. Large, vegetated areas without housing, or with low-density housing are found also in town perimeters. The figures illustrate different types of landscapes:

- **Figure 11: Southern Sweden**
  Skåne, the southmost county in Sweden, is to a large extent covered by arable land which is devoid of WUI, Figure 11 (left). The vegetation (non-arable) is dominated by grass pastures, broadleaves (mainly beech) and spruce plantations. The more forested areas are either low density housing areas or intermix WUI. Interface mostly occurs surrounding the arable land areas. Blekinge county, Figure 11 (right), is located in the south-east of Sweden and is dominated by mixed forest. Blekinge is characterized by low density housing or intermix WUI. Interface WUI is scarce. Figure 10 (c) and (d) reveal that Skåne has a low percentage of both WUI and vegetated low-density housing areas while neighboring Blekinge exhibits the opposite.

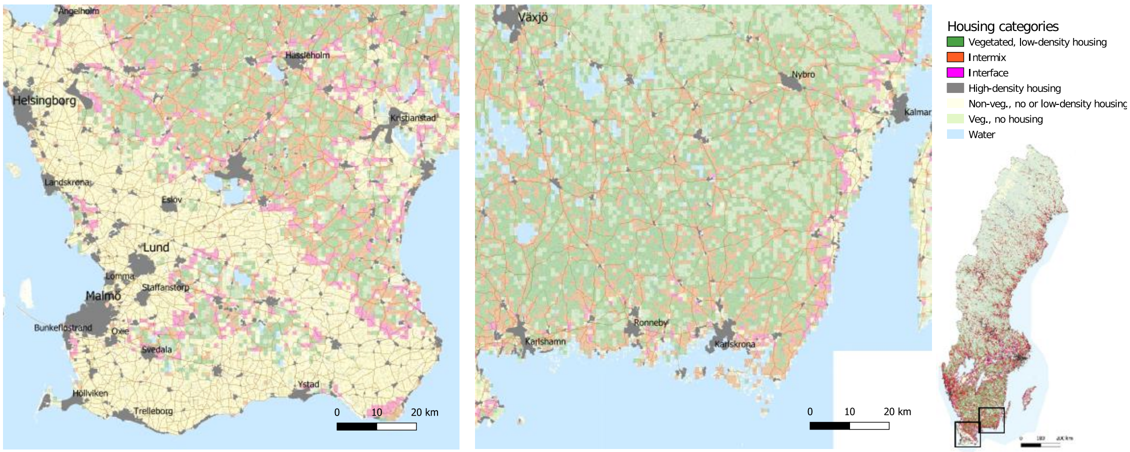

Figure 11. The WUI in southernmost Sweden. Skåne county (left) and Blekinge county (right), together with southern parts of Kronoberg and Kalmar counties.

- **Figure 12: Areas outside large cities**
  The Stockholm area is vegetated, apart from the arable land close to lake Mälaren. Cities with farmland around the city perimeter experience an expected shape of interface surrounding the farmland (e.g. Uppsala). However, when wildland is dominating the surrounding city perimeters the categories transform from High-density building population to Vegetated no- or low-density housing but the occurence of intermix WUI is rather low considering the total amount of people living in the area depicted in Figure 12 (right). This is naturally a consequence of the coarseness of the 1 km^2 grid used on a national and regional scale. Contrary to the surroundings of Stockholm there is a high degree of intermix WUI around the country's 2^{nd} largest city, Göteborg (eng: Gothenburg), Figure 12 (left). The coastal line and the islands of the archipelago exhibits a lot of wildfires during spring due to the tradition of spring burning of garden litter and last season's grass. The high occurrence of wildfire in this area coincide with a high density of intermix. Also, the interior, east of Göteborg, has a high portion of intermix and interface WUI is mostly found enclosing arable land.

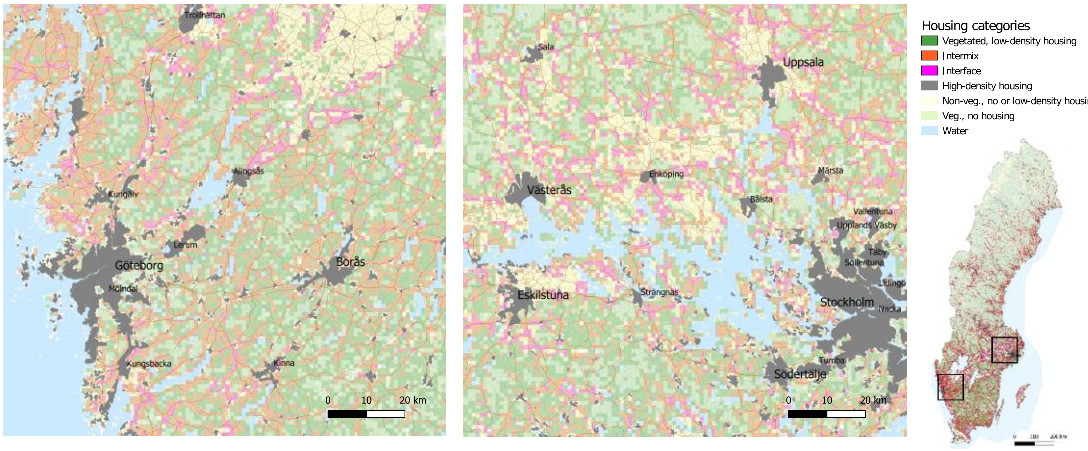

Figure 12. The WUI outside (left) Göteborg and (right) Stockholm. The right figure also partially includes the 2014 Västmanland fire area, located north-west of town Sala

- **Figure 13: Mid Sweden**
  Mid Sweden, exemplified by parts of Gävleborg and Dalarna counties, are low populated and housing is centralized around watercourses and lakes. Vegetation is dominated by pine or spruce stands. While Dalarna (southwest in Figure 13 (left)) exhibits a scatter of intermix within a predominantly no-housing vegetation the WUI of Gävleborg (north in Figure 13 (left) and most of Figure 13 (right)) is clustered along the rivers and associated roads running northwest to south east). In these areas the interface WUI is more common compared to the scattered Dalarna. Figure 13 (right) shows the area around Ljusdal town. West of Ljusdal is Ljusnan river, around which the Ljusdal fires damaged over 30 structures during the summer of 2018. None of these were in a WUI area given the definitions used here.

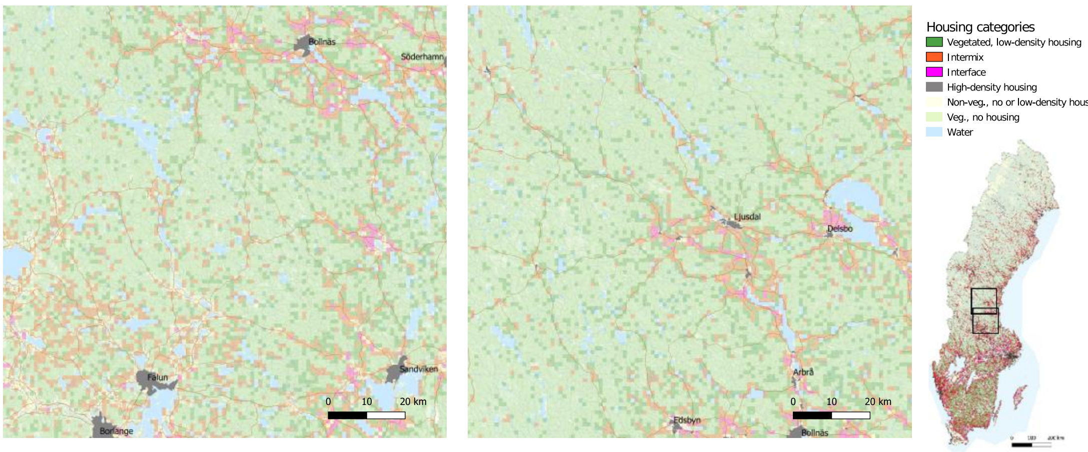

Figure 13. The WUI in parts of Dalarna and Gävleborg counties, representing central Sweden.

- **Figure 14: North Sweden**
  North Sweden, exemplified by coastal parts of Västerbotten and Norrbotten counties, are dominated by conifers. The low-density population results in a vegetated area in which mostly no-housing occurs. Housing, and therefore also the WUI is, like in mid Sweden, centralized around rivers. Intermix dominates and interface is even more scarce than further south, Figure 14

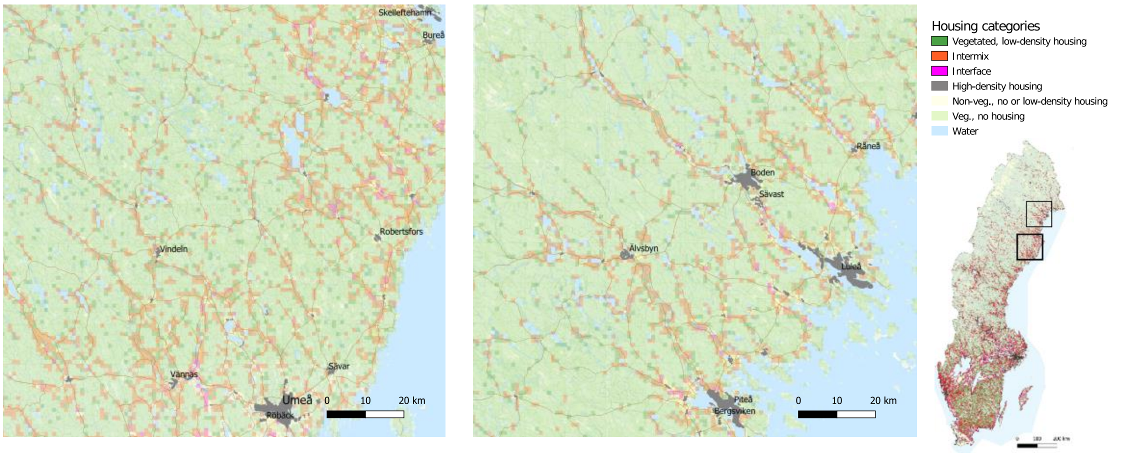

Figure 14. The WUI in the coastal areas of Västerbotten and Norrbotten counties, representing the far north of Sweden.

3.2. The extent of wildfires

Wildfire occurrence probability is predominantly a function of human activity, such as population and infrastructure density (Bradshaw *et al.,* 1984; Hawbaker *et al.,* 2013) as well as land use (Syphard *et al.,* 2012). Both wildfires in general and large wildfires in Sweden are initiated in vegetated areas in proximity to urban areas. The average fire occurrence probability in Sweden is 0.013±0.03 (Figure 16 (Left)) but with a wide range (0 - 1.0 fires/yr/km^2). The highest occurrences are found in some areas around Stockholm and Gothenburg with 0.56 and 1.0 fires/yr/km^2, respectively.

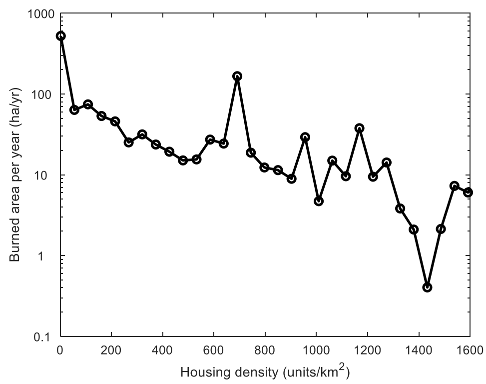

Figure 15. Influence of building population density on annual burned area

Ignition does not necessarily lead to a spreading fire. The burn probability map in Figure 16 (Right) show areas were significant spread is likely. The figures indicate that large fires occur in areas with low population density and less resources to suppress a fire, just as previously described by Sjöström & Granström (2020) on population data aggregated to regions.

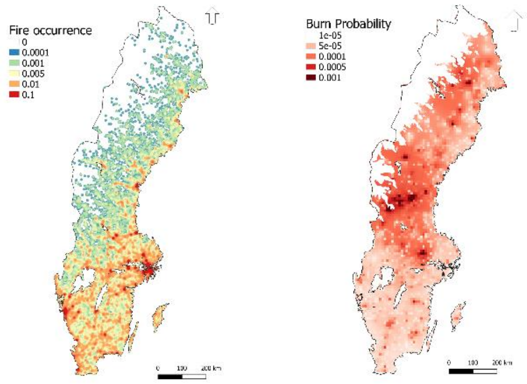

Figure 16. (Left) Fire occurrence (fires/yr/km²), (Right) Burn probability (>1 ha). Data from 1996-2018. The numbers on the legend represent the lowest value associated to the corresponding colour.

A longitudinal variation in burn probability is also indicated in Figure 16 (Right) where the highest burn probability is in the inland mid Sweden (the south-boreal/boreal vegetation zones). The results deviate slightly from the results by Drobyshev *et al.*, (2012), who found the highest burn probability further south, in the Halland and Stockholm counties, i.e. more in line with Figure 16 (Left). The different results have a few plausible explanations: Firstly, Drobyshev and coauthors included all fires, not only the ones > 1 ha. Secondly, large wildfire incidents since 2014 have significantly shifted the highest burn probabilities compared to the 2012-study.

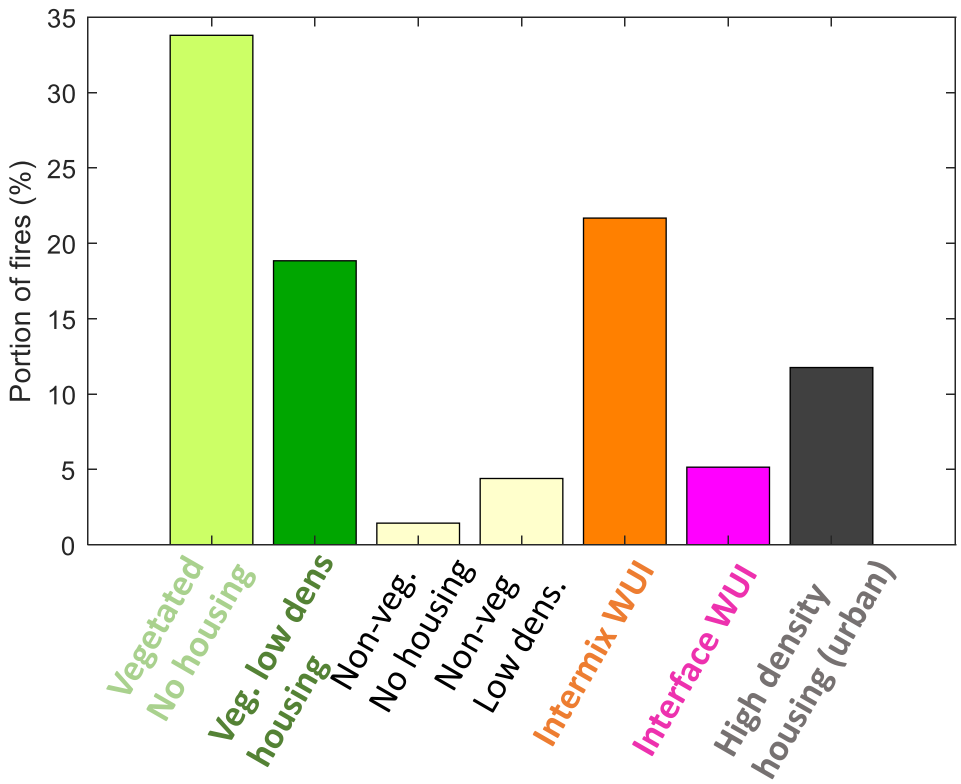

Figure 17. Occurrence of fires (> 1 ha) categorized by the WUI categories at the ignition point

The occurrence of fires within the WUI show that about 30 % of the fires are ignited within the WUI, most of them (22 %) within Intermix zones, Figure 17 while the majority of wildfires above this threshold are ignited within vegetated no- or low density housing areas (53 %).

3.3. Fire service density

Intermix settlements and housing in vegetated, low-populated areas differ from the high-density areas in response time for the fire service; the mean minimum distance via the road network between any fire station (manned, unmanned or volunteer) and an intermix structure is 12 km, whilst the same distance for high-density housing is 6 km. Figure 18 shows significant differences in distance between all housing categories. Over 10 % of the intermix and vegetated, low-density building population has more than 25 km to the nearest fire station.

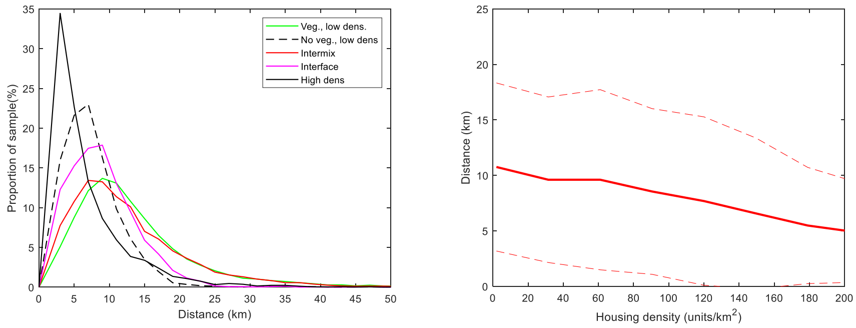

Figure 18. (a) Distance between structures and the closest fire station for different housing areas and (b) Housing density vs. minimum distance to fire station. Lines are mean and ± one standard deviation.

Additionally, the closest fire station to structures within the intermix and low-density housing areas are almost exclusively unmanned, Table 6. Sjöström & Granström (2019) showed that the time to arrival for a dispatch has an exponential correlation to the final burnt area. Thus, Many structures in low-density housing areas or intermix WUI are indirectly more likely to be exposed to large wildfires.

Table 6. Ratio of nearest fire station type for the different housing categories

	Veg., low-density	No veg, low-density	Intermix	Interface	High-density
Manned fire station	8.1 %	13.6 %	12.3 %	15.4 %	37.0 %
Unmanned fire station	74.7 %	70.7 %	73.6 %	73.4 %	54.8 %
Volunteer	17.2 %	15.6 %	14.1 %	11.2 %	8.1 %
Sum	100 %	100 %	100 %	100 %	100 %

It can be assumed that the response time for different populated landscape categories would diverge even more than the response distance, especially since the turnout time for fire stations differ, but also since the travel time is longer in low populated areas: housing are reached by gravel forestry roads, which require that vehicles drive at low velocity. Additionally, forestry roads are mostly dead-end roads. An example is the road network for part of the 2018 Ljusdal fires. Figure 19 shows a few houses that were located at the end of forestry roads accessible from one point only. Although the ongoing fire burned with low intensity the fire management decided to not defend these structures with ground forces due to the risk of falling trees injuring firefighters or blocking the only exit pathways (Granström, 2020).

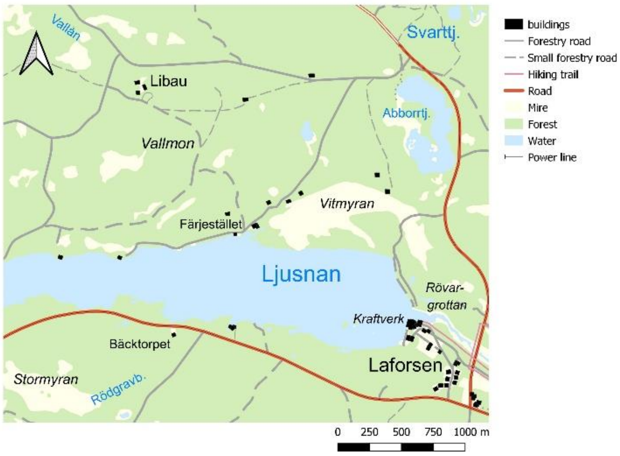

Figure 19. An excerpt of the road network and structures in the 2018 Ljusdal fires. Notice the lack of two-way accessibility on forestry roads west of Färjestället and east of Vitmyran, that is typical of the Swedish road network in low-populated areas. Map based on Terrängkartan (Lantmäteriet, 2018).

3.4. The WUI at community level

The WUI at community level is exemplified in Figure 20. The intermix perimeter surrounding Berga extends 40 m from the wildland into the village and 56.4 m from housing centroids into the wildland. As seen in the Figure, urban geographical centers are not included in the interface, as they are deemed to lie too far from the vegetation fuel in the definition set up in chapter 2.4. The modified WUI definition aimed for the community level defines most buildings in this rural village as interface structures, the pockets of buildings around the village as intermix and isolated buildings further away as non-WUI (low density housing areas).

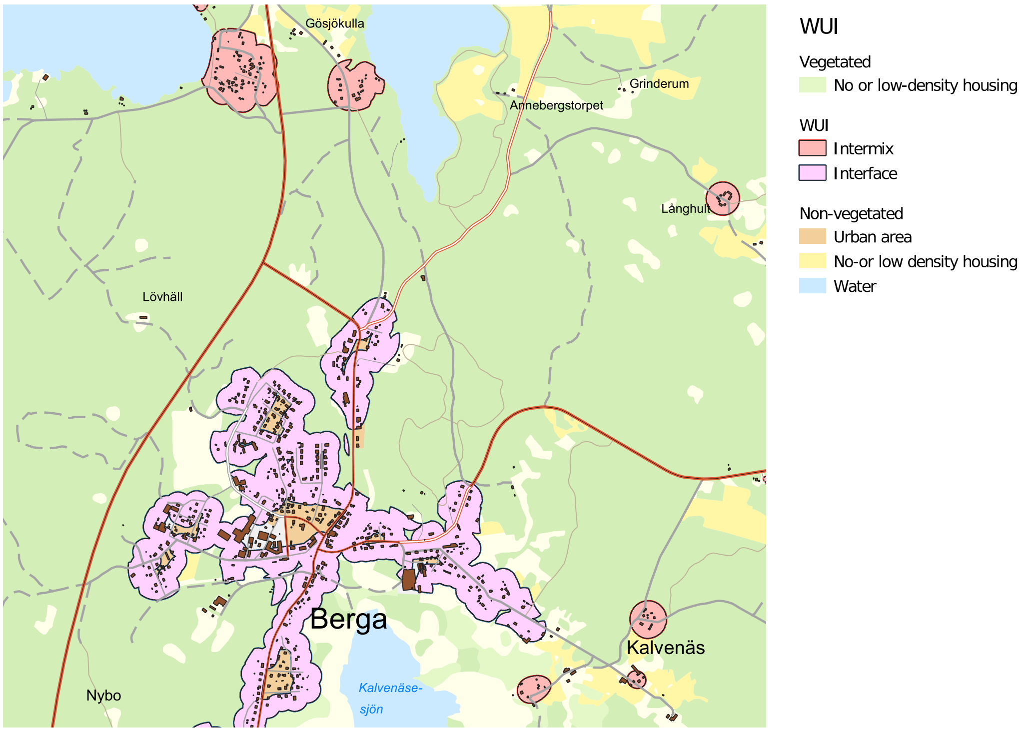

Figure 20. Berga WUI at community level. Intermix is coloured bright red and interface is drawn in bright purple.

3.5. The WUI at property level

The main vegetation type, assessed in a 10 m buffer zone around every residential building in Sweden is *vegetated other open land*, i.e. grass or herb covered land. It accounts for about 50 % of all the combined 10 m buffer zones around all buildings in Sweden, Figure 22 (left). The vegetation raster upon which the analysis is conducted does not specify exactly what type of open land this is, and a managed lawn cannot be distinguished from an unmanaged one or pasture or heathland although these vegeteation types constitutes vastly different fire hazards. However, the results provide a general description of whether or not a defensible space exists. Around 20 % of all residential buildings are <u>fully</u> surrounded by *other open land* (both vegetated and non-vegetated, including non- to low-vegetated natural land covers such as sand dunes and alvar) within a perimeter using a 10 m buffer, Figure 21.

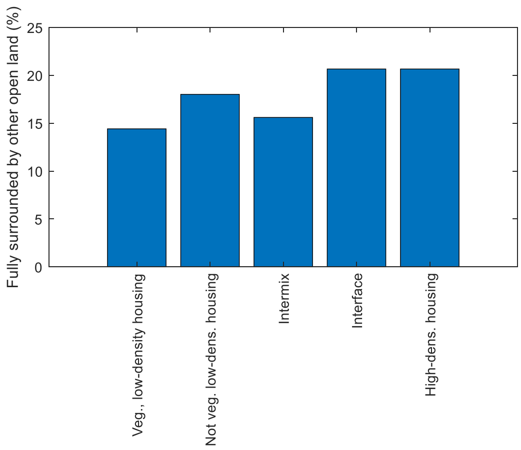

Figure 21. Proportion of residential buildings that are fully surrounded by other open land

Only intermix and vegetated, low-density housing areas have significant portions of conifer, clear-felled and mixed forest in their immediate (10 m) surrounding. Increasing the buffer zone width to 50 m and thereby including surrounding often outside of gardens has only little effect on the result, Figure 22 (right). It highlights that the vegetation around intermix and vegetated, low-density housing to a larger extent consist of fuel-rich vegetation such as conifer stands (16 and 19 % for the two housing categories respectively) and clear-felled land. The portion of vegetated other open land decrease in the 50 m buffer zone while the portion of arable land increases by more than a factor 3. The component of deciduous trees varies very little between the different housing categories and is around 20 % within 10 m from houses in the WUI as well as in the high- or low-density areas.

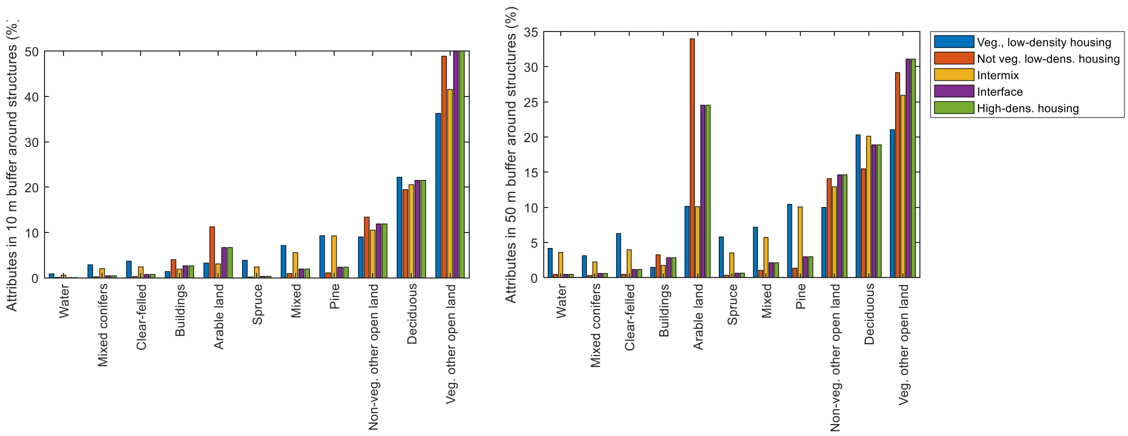

Figure 22. Characteristics around residential structures in a 10 m (Left) and 50 m (Right) surrounding, respectively

3.6. Typical examples of WUI at property level

69 of the 170 structures in the rural settlement were dwellings and the rest divided between 86 outbuildings (typically garages, guesthouses or larger storage buildings) and 15 industrial buildings. All buildings had at least one direct boarder to wildland. The characteristics of the immediate surroundings are exemplified in Figure 23.

Figure 23. Characteristic surrounding vegetation of the rural village Berga (photos: Johan Sjöström and Eniro).

From the suburban townhouse settlement 61 dwellings and 5 outbuildings were included due to their direct boarder towards wildland. The surrounding is dominated by conifers with occasional deciduous trees close to gardens, Figure 24. All were one or two storey buildings and all included a small patch of garden.

Figure 24. Characteristic surroundings of the suburban townhouse settlement (photos: Johan Sjöström and Eniro).

The façade material of the townhouses were 100 % timber and roof material 100 % clay tiles. Even though this does not hold on a national level these characteristic materials represent an overwhelming majority of townhouses throughout Sweden. The single dwellings in the rural village were more diverse considering building envelope material but more than half of them had timber facades and most of the rest divided between incombustible mortar or brick, Figure 26. A study of houses changing owbers during 1997-1998 estimated that 80 % of those single dwellings had timber facades (Molnár, 2003). Outbuildings are, to a larger extent than dwellings, completely built in wood.

The roof materials are dominated by tiles. That usually include tiles placed over a wooden lath grid under which bituminous waterproofing (generally called *takpapp* in Swedish) safeguards the house from moisture, Figure 25. The clay tiles roof systems dominate most dwellings outside big cities in which copper or steel are more numerous. The roofs of outbuildings are mostly either tiles or corrugated metal sheets, Figure 26. Even if no examples of it appeared in this study, only bituminous waterproofing (without the clay tiles layer) also occurs on some outbuildings throughout the country.

Figure 25. Typical clay tile roof system including a grid of wooden lath and bituminous waterproofing. Photo DW bygg, with permission.

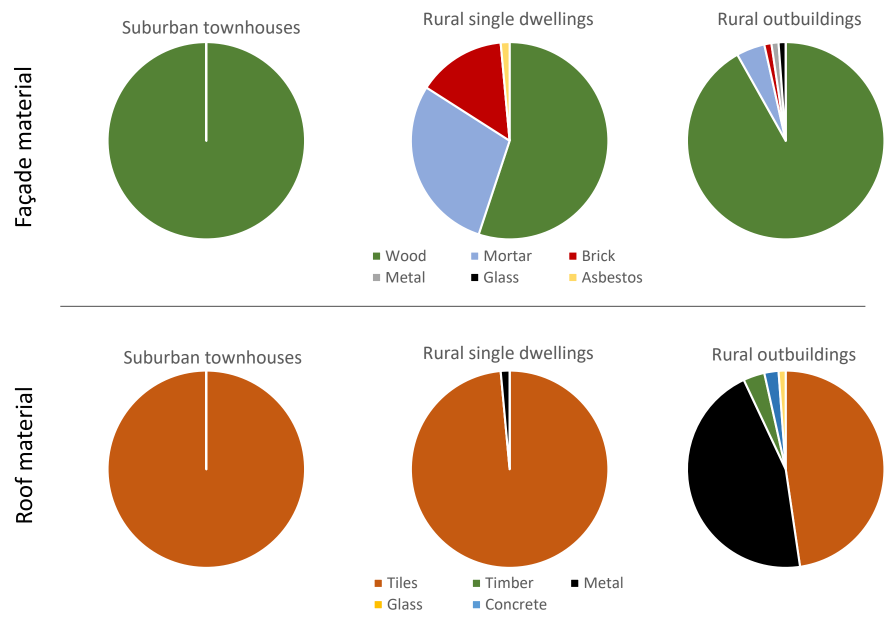

Figure 26. Material in façades (upper panels) and roof (lower panels) for the rural village.

The minimum distance to the wildland from the façade peaked at around 10 meters for both rural dwellings and suburban townhouses. For the single dwellings this is often the distance to the property line and for townhouses it sometimes includes a strip of cut lawn outside each individual garden in order to enable sunlight and limiting tree litter from reaching the gardens. A few of the single dwellings were actually just adjacent to the wild vegetation and while the span for townhouses ranged from 3-14 meters some single dwellings had gardens reaching up to 34 meters, Figure 27. The outbuildings were to 40 % located just at the property line, thereby just adjacent to wildland fuel and the distribution thereafter monotonically declined with longer distances.

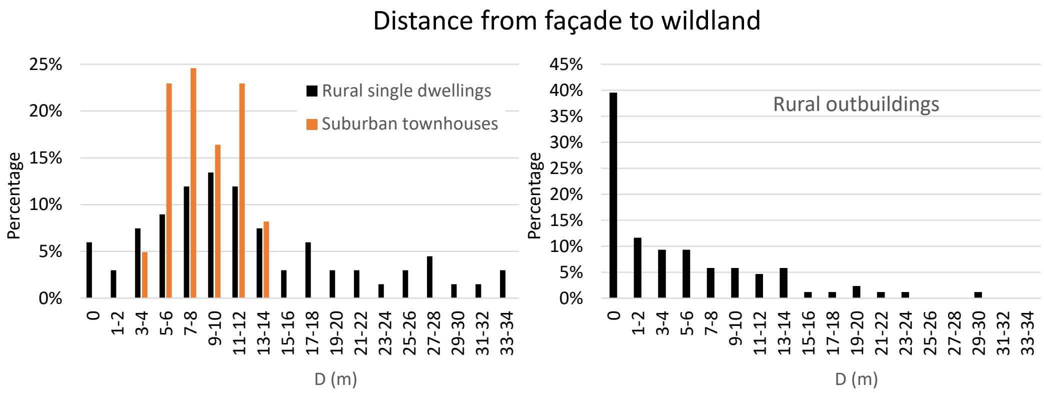

Figure 27. Closest distance from façade to wildland in for the rural village suburban townhouse dwellings (left) and rural outbuildings (right).

Figure 28. Examples of distances from façade to wildland. (1) Single dwelling directly adjacent to wildland; (2) suburban townhouse with typical medium distance for this settlement and (3) rural dwelling with a long lawn between house and wildland. Photos: Johan Sjöström.

The fuel load in the gardens and up to the facades show that the majority of buildings have low or medium exposure to the façade. The medium risk level is more common in the suburban townhouses, most probably a direct consequence of the limited space compared to rural single dwellings. Even though the fractions of risk levels agree, the nature of the fuel differs between them. For the townhouses less vegetation is present close to the facades whereas it is more common with non-vegetation fuel, often composed of garden furniture, toys or undisposed waste, Figure 30. Vegetation fuels, although not as common for townhouses, can sometimes be very large in comparison to the distance and extent of façade as photo 3 and 4 in Figure 32 exemplifies. For rural areas the fuels close to facades are often more miscellaneous such as wood pallets or tires and the vegetation fuel is often unmanaged grassland or trees close to outbuildings (photo 1 in Figure 28 and photo 3 in Figure 31).

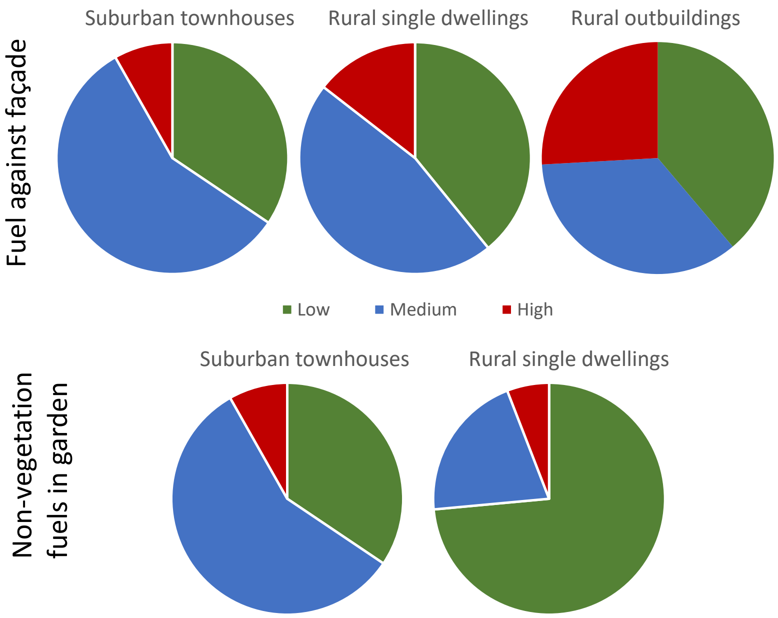

Figure 29. Fractions of risk concerning fuel against facade (upper charts) and non-vegetation fuels in the gardens (lower charts).

The occurrence of low/medium/high risk due to vegetation fuels is strongly correlated to the equivalent concerning non-vegetation fuels. Keeping in mind that the risk is evaluated in only three distinct levels the correlation between the two kinds of fuels has a strong correlation between them. Thus, properties with a high risk due to vegetation fuels are likely to exhibit a high risk due to non-vegetation fuels.

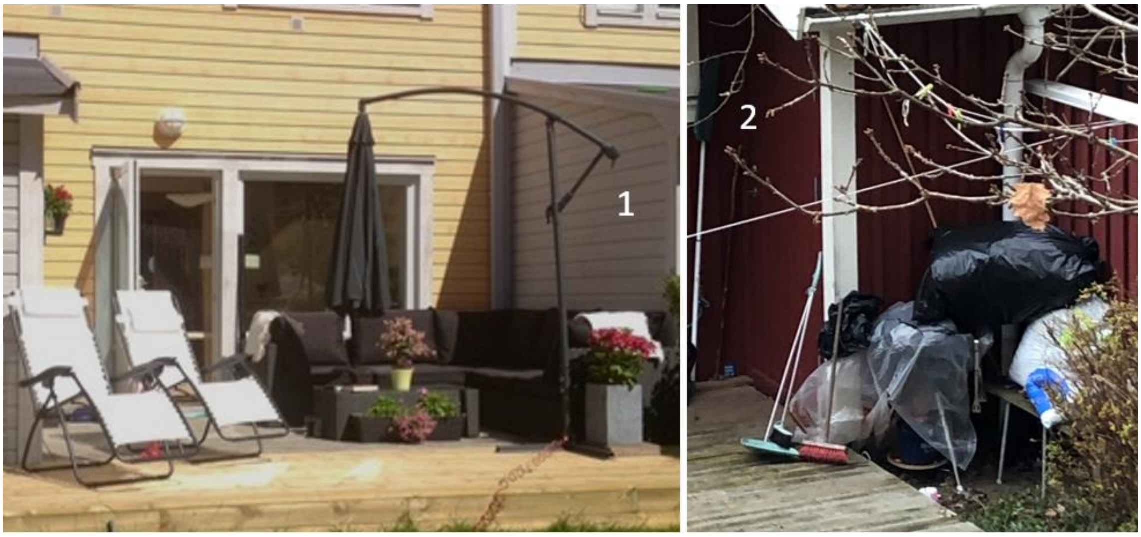

Figure 30. Characteristic non-vegetation fuels in gardens of suburban townhouses. (1) Characteristic garden furniture. Photo: Gabriella von Martens, with permission. (2) Non-disposed waste stored against the façade.

Semiconfined spaces are ubiquitous both for townhouses and rural dwellings, Figure 31. They often contain fuels since which most often consist of garden furniture and wood fuel. In townhouses the wood fuel storages are often very small while they can be substantial around rural homes.

Figure 31. Non-vegetation fuels in semiconfined spaced directly adjoining homes. (1) Characteristic wood fuel pile with metal rain protection in suburban townhouse. Photo: Stella Norrvi, with permission. (2) Wooden porch with wooden roof and timber storage under the floor in rural dwelling. (3) Storage of wood fuel, car tires, wooden pallets and miscellaneous under a metal rain protection at the façade of an industrial/storage outbuilding. The surrounding vegetation is unmanaged grassland. (4) wooden porch with plastic ceiling filled with combustibles, including and old motorbike.

Ornamental plants differ significantly from flammable conifers such as *Thuja* or *Cupressus* to deciduous plants which are less fire prone such as Lilac (e.g. *Syringa vulgaris*), Figure 32.

Figure 32. Some examples of vegetation fuels in gardens. (1) Plaster house with wooden extension on a garden with lots of deciduous and not very flammable ornamental plant. The forest behind is coniferous except for trees just adjacent to the garden. (2) Wooden single dwelling with nearby garage and storage outbuilding and two large Thuja Occidentalis next to the façade. (3) Cupressus leylandii growing up to wooden façade and deck at suburban townhouse. The vegetation around is dominated by Calluna. The photo is taken during autumn and residents confirm that the deck is filled with tables and chairs during summer season. (4) suburban townhouse surrounded by Dasiphora fruticose, commonly called Tundra rose (Ölandstok – Swedish).

The slopes from the wildland to the houses are often upwards, with houses situated on high ground for views and sunlight. However, around half of the homes in our study have a negligible slope towards the building and about a quarter has a mild upwards slope (< 30 °). Contrary to many other countries, most buildings do not have any boundaries towards the wild (74 % in our study). Those that do usually have a wooden fence and sometimes metal ones, Figure 33. Metal fences are not considered aestetically pleasing and are often overgrown with climbing species such as bindweed (*Convolvulus arvensis*) or honeysuckle (*Lonicera caprifolium*).

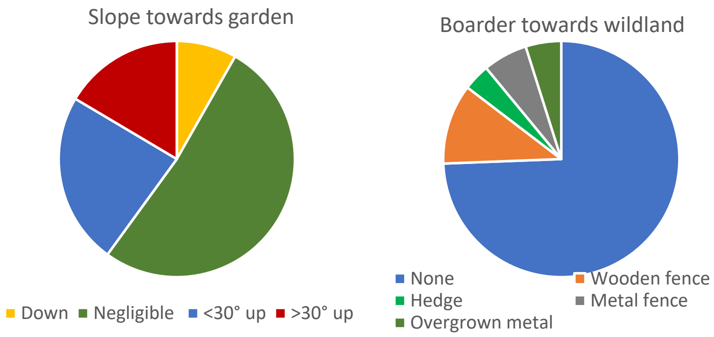

Figure 33. Fractions of risk concerning vegetation (upper charts) and other (lower charts) fuels against the facades.

There are several examples that areas outside property boundaries are to some extent cleared of full grown trees. This could be just a few meters for townhouses to longer distances for single dwellings. Although this often safeguards the home ignition zone it does not automatically mean a reduced fire hazard as the area can be covered in unmanaged grassland or heather (e.g. *Calluna vulgaris*), Figure 34.

Figure 34. Cleared areas outside property lines or large managed lawn gardens. (1) Cleared trees outside garden of one single dwelling within the forest. (2) area with few trees but with unmanaged grassland just outside garden. (3) Cleared area outside garden covered with highly flammable Calluna. (4) Large managed lawn stretching far from the building. Photos: Johan Sjöström.

Comparing the distances to the wildland, the vegetation fuel load and the material of the building envelope with the occurrence of semiconfined spaces containing fuel and the level of non-vegetation fuel against façade one cannot find any correlation indicating risk awareness with regards to wildfires by the homeowners. Thus, a wooden façade or a vulnerable porch does not dictate how well the garden fuel is managed or whether fuels are stored against the façade.

4. Discussion

4.1. The WUI at different scales

This report discusses the WUI in Sweden on four different levels. The national, the regional, the community and the property level. Maps of the WUI are not relevant for the property level where photos and homeowner knowledge are far more important. We have shown here that the national and regional level can be described by the same type of resolution and same algorithm of calculating the WUI. The definition by Radeloff (2005) can be applied to the Swedish context on a national or regional level and the information in these maps can be valuable for authorities in regional planning or resource allocation and can be used in combination with fire risk maps (e.g. Figure 16) to identify homes and other structures with a high vulnerability to wildfires.

Since the American WUI maps are generated on census data, in which the building blocks that constitute the polygons in which the building density is evaluated are constructed from anthropogenic (e.g. roads, power lines, county lines) or natural (e.g. rivers/streams, steep decsents) barriers the evaluated areas follow more natural patterns for the buildings (US Census bureau (2002). Additionally, the size of these polygons automatically shift from a few 100 m^2 to very large 10s of km^2 with the gradients and complexity of the landscape patterns. Therefore, the maps are easier to use from national to community scale. Few countries have available such type of information and thus the possibility of using a regular grid for the national and regional levels represent one way forward.

Naturally the result should depend on the scale of the grid size. Choosing too small grid cells would yield too strong gradients of building density and thus a problem of not finding the interface WUI region. Also, small dense settlements could be defined as high density housing even though it should classify as WUI from by visual inspection. Too large grid cells would define many houses deep within dense settlements as WUI. In this study produced results for all buildings in Sweden on a 1 km^2 grid but these results should be compared to studies of varying grid cell size and, at least for a portion of the country, to constructed polygons like the US Census data before its results is fit for operational use.

It is also clear that the national/regional mapping on a regular grid is not useful at community level, as seen in Figure 35. On this level, greater resolution is needed for the information to be useful for a community or municipality. This information is more focused on guidance for mitigating strategies such as thinning or fuel management around properties and for preparedness of homeowners in specific locations.

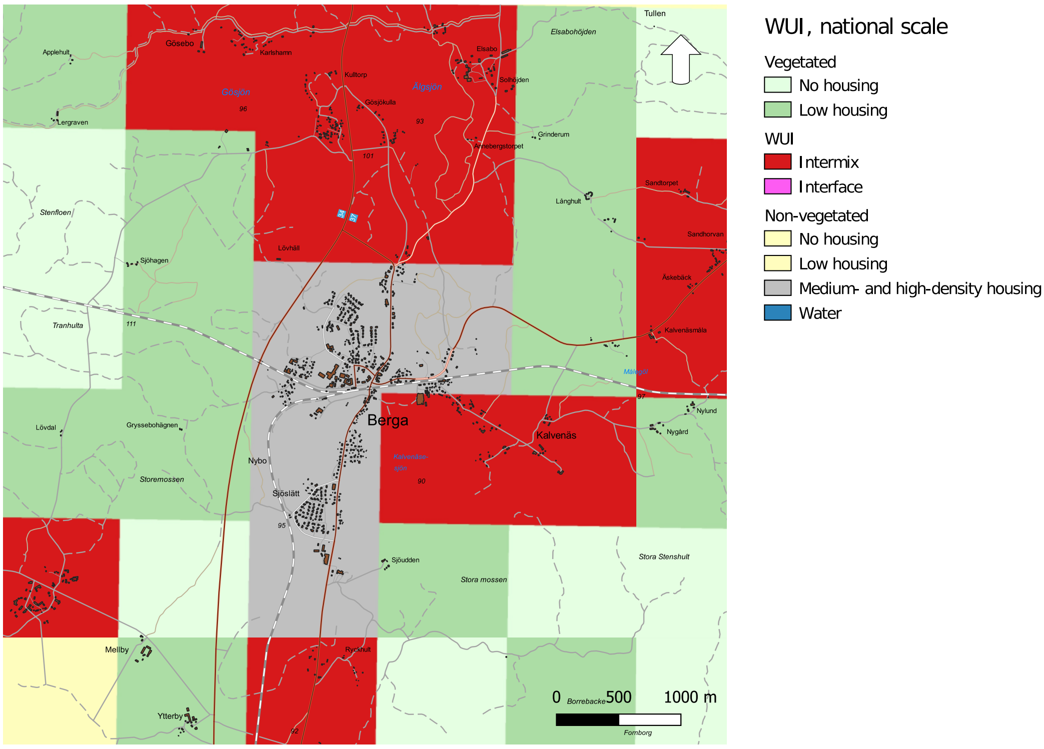

Figure 35. National WUI map at community level, showing that the result is dependent on the included area of analysis. Note that the colour scheme of the figure differs from other WUI maps in the report.

Using the 1 km^2 resolution at the community level clearly misses this target as most part of the Berga village is classified as non-WUI high density housing surrounded by intermix and low density housing. Instead, the higher resolution algorithm described in Table 3 and exemplified in Figure 20 describe the community better.

The regional scale maps, presented in Figure 11 - Figure 14 shows the pattern of the WUI in Sweden. Comparing to USA, where this definition of the WUI originates from, exposes some similarities but even more differences. Given that data extracted from a regular grid can be compared to the ones generated from Census data we focus on three northern states Washington, Oregon and Maine. Combined, these resembles Sweden in both size, population and land use. It is clear that the Swedish map is more mosaic compared to the American. The Swedish intermix is scattered all over most regions while the American regions are more clearly divided in distinct patches (Martinuzzi, 2015), Figure 36.

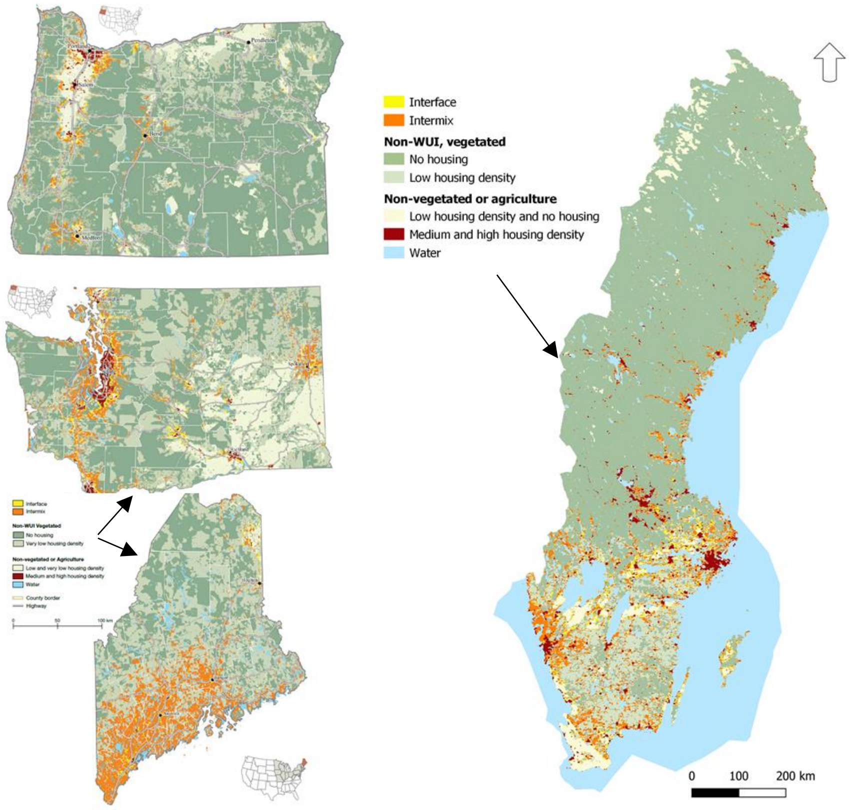

Figure 36. (Left) The WUI of the states of Oregon, Washington and Main in the USA from Martinuzzi (2015). (Right) The WUI of Sweden.

For Sweden the WUI constitute 14 % of the area and 23 % of the building population whereas it for the three American states combined covers 8 % by area and 39 % by buildings. Thus, a larger portion of these three states are strictly wildland or low densely populated while the houses are located in regions that to a higher degree are categorized as WUI. While the most American WUI buildings are situated in the interface (24 % of all buildings) rather than intermix (14 %) the Swedish WUI buildings are overwhelmingly in the intermix (20 %) as opposed to interface (3 %). The fraction of buildings in low density areas is somewhat larger in Sweden (7 %) compared to the three comparative states (5 %). However, in this comparison we should keep in mind that most of the rural village of Berga in Småland was considered High density (urban) in our analysis, this not situated in the WUI, Figure 35.

Compared to a European region one can mention Catalonia in which 64 % of the building population are in the interface (7 % by area) and 12 % in the intermix (3 % by area) (Alcasena *et al*, 2018). These number do not by far compare to the Swedish situation. This result highlights even more the need for altering the method of evaluation on different scales and, perhaps, adjusting it to the specific needs of different countries. The differences between the regions and countries may be many. Factors that ought to play a role is the great partition, a land reform in Sweden during mid 1700s and that Swedish settlements have been focused around industry rather than agriculture.

4.2. The extent of wildfire

Wildfire data produced in this project has solely depended on historic (1996-2018) fire incidents. Burn probability modelling is not the ideal way to present the likelihood of a spreading fire since it assumes stationary meteorological and landscape conditions, as well as a constant ignition frequency. However, little is known about the fire behavior of natural fuels in Sweden today, thereby ruling out more sophisticated efforts such as fire growth simulations. The purpose of this part of the study has been to roughly point to the areas with highest occurrence of wildfire as an initial step towards a future wildfire risk assessment.

4.3. Typical WUI at property scale

WUI is an intrinsic part of the scenery. Wildland (although mostly in the form of production forests) is almost continuous throughout the country with settlements appearing as villages or isolated buildings spot wise in the boreal landscape. Combustible façades are very common, but it is likewise comparably long distances to highly combustible fuels.

Risk perception regarding wildfire among house owners in Sweden appears to be low. Timber façades are common, and no consideration is taken to increase the defensible space or to decrease the fuel load in the garden if the house is built with combustible materials. Instead other factors drive the fuel distribution around buildings:

One factor is the low angle of the sun at these latitudes. The need for shading from trees is low and instead homeowners often do their best to clear the vicinity of tall trees. It is common to ask the landowner of the surrounding land for permission to clear the closest buffer zone of tress in order to enable sunlight into the garden. While this can have a positive effect on litter and for the threat from crowning fires it also enables a faster drying of the surface fuels around the garden. It also enables the growth of other fuels associated with fast spread in low intensity fires such as unmanaged grassland or heather (in particular *C vulgaris*).

The abundance of wooden facades which are sensitive to moisture result in a general recommendation to remove plants in direct contact to the outer walls with natural consequences for fire vulnerability. However, this can also imply that broadleaved species are changed for more flammable coniferous species like *Cupressus* or *Thuja*. Also Roofs are cleaned from needles to avoid moss establishment and associated moisture problems. Miscellaneous fuels are stored in semi-open spaces for rain protection. Outbuildings are placed at property edges to maximize garden space. Regardless of motivation, some of the factors that determine the fuel load and distribution are positive from a fire protection point of view.

There is a balance of needs that need to be taken into account and typically wildfire is of low concern. No large fire has yet to struck a suburban townhouse settlement. Residential buildings damaged in wildfires are single buildings burning in from very loal wildfires in gardens or single isolated building within the forest burning in large forest fires. Most damaged buildings are either seasonal homes or outbuildings. However, the last few years have really showed the potential of wildfires in Sweden and the risk of large destruction of denser settlements is far from negligible.

5. Conclusions

This study makes an attempt to describe the Wildland-Urban-Interface (WUI) of Sweden from a wildfire perspective on 4 characteristic levels: The national level (describing the country as a whole), the regional level (in which the gradients within regions can be identifies), the community level (which identifies vulnerable areas and settlements) and the property level (in which the actions of homeowners are described).

In lieu of national, or even European, definitions of the WUI we use the ones developed for North America, and USA in particular, Radeloff *et al* (2005). Since the Census polygon data on which the WUI characteristics in the USA are evaluated are not available for most other countries, we simply apply the definitions on a regular 1 km^2 grid throughout the country on a national and regional level. The results follow expected patterns across the nation, the WUI is scattered over Sweden, but the greatest extent is found outside Stockholm and Gothenburg and in Blekinge county. The Swedish WUI is characterized by scattered housing and settlements intermingled with the forest. However, the wildland reaches all the way up to, and into, the city perimeters.

We show that the method is too coarse for evaluations on a community level. Instead, a method adapted for Swedish landscapes is defined and exemplified on a rural village in southern Sweden. Assuming that the 1 km^2 regular grid can be compared with Census based data we note that a larger area of Sweden is WUI compared to three comparable states in USA (Washington state, Oregon and Maine). However, the portion of residential buildings that lie within the WUI is larger in USA (39 %) than in Sweden (23 %). Comparing to the Catalonian region of Spain the portion of residential buildings within the WUI is even larger (64 %). If these differences reflect genuine differences in portions at risk of wildfires or if they are attributed to the areas of evaluations (census blocks or regular grid) remain to be investigated. Further research should evaluate the grid size effect of regular grids and also a true comparison to Census data for the same region.

While the interface is more common in the densely populated areas the intermix is more common in low density regions. It is also those regions that are mostly struck by large wildfires and the buildings destroyed in large fires actually often belong to the low density vegetated areas. This also occurs in regions where firefighting resources are scarce. Although none of the last few decade's wildfires has directly threatened larger settlements the possibility of a fire spreading into more densely populated areas cannot be discarded.

One large difference between the interface and the intermix WUI is the near vicinity to flammable conifer forests. Buildings in the intermix and the low density vegetated land exhibit conifers, mixed forests or clear-felled areas in their closest surrounding are about 25-30 % in stark contrast to buildings in the interface in which the corresponding number is about 5 %.

There is little risk awareness among homeowners regarding wildfires: An inventory of the Swedish WUI at property level shows that the defensible space is not larger for structures with combustible (timber) facades, and gardens with a high degree of vegetation fuel have also a high degree of other fuels, as well as unmanaged lawns. Combustible (timber) façades are common, and the fuel load within the home ignition zone typically consists of piles of firewood and coniferous ornamental plants. Decisions on fuel management is mostly done based on enabling sunlight (with a comparatively low angel) or moisture protection of buildings.

6. References

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